**Document Title: Procedure for Manufacture of Mandrel Elbows (Hot Formed)**

**Mandrel Plant 2 (Large)**

## 1.0 SCOPE

This procedure outlines the process to manufacture CS and AS Mandrel Elbows and Bends (Hot Formed, 2" NPS to 8" NPS [Mandrel 1] and 10" NPS to 24" NPS [Mandrel 2]) from Seamless Pipe Lengths and ensure that all the manufactured fittings comply with stated requirements and are manufactured under controlled conditions. Smaller and thicker size pipes are used to manufacture larger and thinner size fittings.

## 2.0 POLICY

In small and medium-sized businesses, in particular, considerable potential exists for increasing productivity and efficiency in economic and ecological terms, because current production is often based on empirical experience and manual skills. Taking the example of pipe elbow production by the so-called 'Hamburg Process', the process is detailed here.

## 3.0 METHOD

**PRINCIPLE:**

Here, heated pipe sections are pushed over a horn-shaped mandrel, which defines the expansion and the radius of curvature, into a one-piece and robust fitting.
In the traditional process, forming precision and reliability are low. The Wall Thickness of the convex side is thinned and cracked due to tension and the Wall Thickness on the concave side is thickened and wrinkled due to compression. This Technology aims to avoid uneven thickness, avoid / reduce any human errors and ensure high precision, focused reliability and continuous repeatability.
It brings with it numerous benefits in terms of reduction of processing operations, time and total process costs.
Fittings manufactured by using hot mandrel bending have advantages of small thickness deviation and shorter bending radius than those of any other bending method type.
Minor Walled, Thin Walled and 180$^{o}$ Fittings with even wall thickness can be achieved using this process.
If all the Technological parameters are set reasonable, this process guarantees all parts of the fittings wall thickness remains EVEN in the forming process.

**RAW MATERIALS** (refer separate procedures for details)**:**

Pipes are selected after Internal Inspections (Visual, Dimensions, Properties, etc) and cut to the required lengths (refer Pipe Length Chart), on Hacksaw or Plasma Cutting Machines. Starting Materials shall be free from burrs, cracks, nicks, gouges, waves, buckles, or other such surface defects that may impede the successful production of the fitting.
Heat Number punching (preferably low stress) is carried out on each cut length, to ensure traceability is maintained throughout the manufacturing process.

**CRITICAL PARAMETERS:**

- Formability of the material: it is necessary for the process to work properly and the fitting, does not break during the application of pressure;
- Friction at the interface: the friction between the die and the piece must be properly calibrated/lubricated;
- Machine parameters: these include times, pressures and movements of the axial cylinders that must be set correctly for the effective and efficient production of fittings.

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## ESSENTIAL VARIABLES:

- Pipe Wall Thickness – same as Chart Indicated Wall Thickness (i.e. within 12.5% fitting tolerance)
- Forming Velocity – set by machine itself, based on 'Pressure of Hydraulic Motor'
- Forming Temperature (of Job) – between 620°C and 980°C
- Pressurizing Component – Hydraulic Motor
- Induction Coil Volt Setting – Start at 0.1kV and increase incrementally with 0.1kV generally every 5 mins, till 0.8kV and 900°C (Job Temperature, achieved by checking with Optical Pyrometer) is achieved. Only then should the Hydraulic (Push) motor be started.


## MANUFACTURING:

The Hot Mandrel Plant is primed to start manufacturing.
Machine Operator to ensure proper Machine conditions are set (Essential Variables) to avoid Over Thinning, Wrinkles, etc.
The Pipe Cut lengths are loaded in the machine on the Draw Bar (the front end of the Draw Bar is welded to the Horn Mandrel and the back end is linked to pushing machine with locks), after application of Lubricant (mixture of Graphite Powder [40%] & Water [60%]; Oil is to be avoided to prevent any fires) on its inner surface. Pipe Cut Lengths are pushed forward along the Draw Bar by a Thrust Ring. The Thrust Ring is fixed on the moving Cross Beam and driven by a hydraulic motor. The Thrust Ring presses against the last Pipe Cut Length and pushes all the Pipe Cut Lengths into the zone of the Horn Mandrel.
The moment the Pipe Cut Length enters the bending and expanding zone, medium frequency induction heating ring is heated and the bending deformation and expanding deformation occurs at the same time in the pushing process. Optical Pyrometer is used to measure temperature and ensure it remains within the acceptable range.
After passing through the deformation zone of the Horn Mandrel, the Pipe Cut Length enters the Shaping Zone.
At the end of the process, the semi-finished fittings fall (from the large end of the horn mandrel) in sequence and can be extracted and directed, if necessary, to the subsequent processing phases.

## SAFETY:

All required safety precautions shall be ensured (Safety Shoes, Safety Gloves, Safety Goggles, Safety Helmet, etc). Specific care to be taken since High Temperatures are involved. Avoid standing directly near the hot mandrel, this area is generally cordoned off.

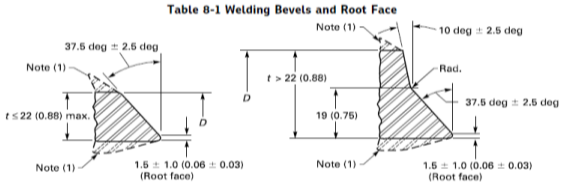
## SEMI-FINISHED INSPECTION:

The QC Engineer ensures that the first piece meets the Visual and Dimensional requirements of Semi-Finished products. He signs the Job Card (which is used for manufacturing details and clearance) as evidence of this inspection and manufacturing continues. More fittings may be inspected in case of large quantities at regular intervals, to ensure control on the process. Eventually the Job Card is signed off by the Machine Operator, after completion of all activities.

## FINAL PROCESSES:

The semi-finished fittings are then forwarded to the Cutting / Machine Shop / Heat Treatment Section / NDT Section / Shot Blasting Section / Rust Preventive application Section / Paint Section, as applicable, for further processing.
Final Beveling operations are generally carried out as indicated (ASME B16.25 / ASME B 16.9), but strictly as per the stated Dimensional Standard.

**Table 8-1 Welding Bevels and Root Face**




| Nominal Wall Thickness, *t*, mm (in.) | End Preparation |
|---|---|
| Less than *x* [Note (2)] | Cut square or slightly chamfer, at manufacturer's option (not illustrated) |
| *x* to 22 (0.88), inclusive [Note (2)] | Plain bevel as in illustration (a) above |
| More than 22 (0.88) | Compound bevel as in illustration (b) above |

GENERAL NOTE: In the illustrations, dimensions in parentheses are in inches; other dimensions are in millimeters.

NOTES:
(1) See section 8 and Figure 8-1 for transition contours.
(2) *x* = 5 mm (0.19 in.) for carbon steel or ferritic alloy steel and 3 mm (0.12 in.) for austenitic steel or nonferrous alloys.

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**TESTING** (refer separate procedures for details):
Samples are drawn from the finished product for Laboratory Testing (Chemical, Mechanical, Hardness, as applicable, as per stated Material Standard).

**FINAL INSPECTION** (refer separate procedures for details):
Final Visual and Dimensional Inspections shall be completed by Inspection Engineer after Final Machining and Finishing Operations, as per the Standard QAP. Tolerances shall be as per the stated Dimensional Standards.

## 4.0 PROCESS VALIDATION

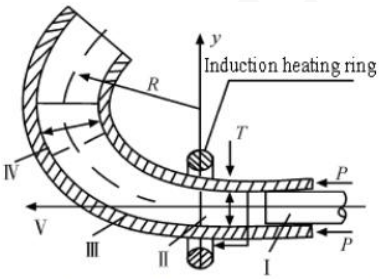
Visual and Dimensional (including Ovality, Outside Diameter, Wall Thickness [using Ultrasonic Thickness Gauge], Inside Diameter, Off Angle, Off Plane, Length, Height, etc) Inspections have resulted in compliances with the Standards.
Material Testing (Chemical, Mechanical [Transverse / Longitudinal], Metallurgical, etc) have resulted in compliances with the Standards.
Since the fittings are Hot Formed (between 620°C and 980°C) and cooled in Still Air, no subsequent Heat Treatment is necessary, unless based on PO or Contractual requirements.

## 5.0 RESPONSIBILITY

This procedure is the responsibility of the Hot Mandrel Machine Operator and Production Head / Incharge.

## 6.0 REFERENCES

Machine Manufacturer's Manual
Research Paper on Hot Mandrel Bending of Pipe Elbows by ResearchGate – Jan 2017
Research Paper on Efficiency of Hot Mandrel Bending of Pipe Elbows by Science Direct – Sept 2017
Research Paper on Technology Analysis of Hot Pushing Pipe Bending and Horn Mandrel Design by ICMEIS - 2015
Dimensional Standards – ASME, MSS SP
Material Standards – ASME, ASTM, IS, DIN, EN



Schematic diagram of hot pushing pipe bending process

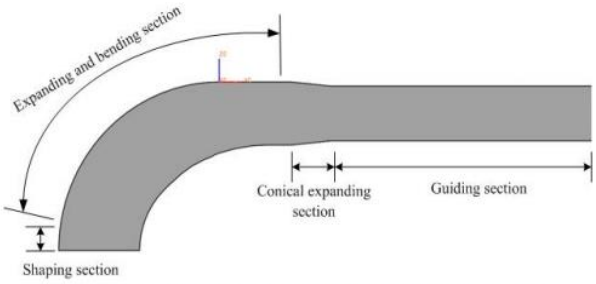
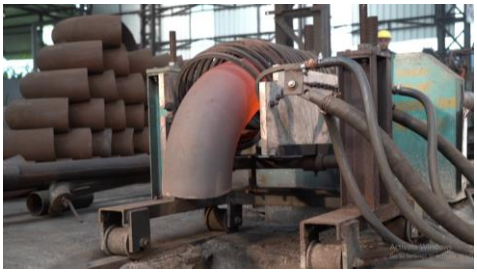


Fig.2 Three dimensional modeling of horn mandrel


**Mandrel Plant 1 (Small)**


**Optical Pyrometer Check (Small)**


**Optical Pyrometer Check (Large)**

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